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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1020336

Project Title

SMART SYSTEM FOR POULTRY WELFARE AND MANAGEMENT

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2019
Grant No. 2019-33610-30180	**Cumulative Award Amt.** $599,942.00
Proposal No. 2019-02319	**Multistate No.** (N/A)
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Project Director

Rasheed, Z.

Recipient Organization

NOVATEUR RESEARCH SOLUTIONS LLC
20110 ASHBROOK PL STE 170
ASHBURN, VIRGINIA 201475069

Performing Department

(N/A)

Non Technical Summary

In recent years, consumers' concerns over hen well-being in conventional small wire cages (called battery cages) has resulted in some of the poultry farms to switch to cage-free housing where hens have the freedom to walk around, spread their wings, and lay their eggs in real nest boxes. This push towards cage-free egg production was further magnified in 2015 when many of the large fast food, restaurant chains, and food suppliers announced their intentions to completely switch from conventionally farmed eggs to cage-fee eggs in US and Canada over the next decade. As a result, many of the egg suppliers have started to make the switch whereas other small and large producers are also expected to follow suit in the face of growing demand. However, the current level of egg production in USA (roughly 100 billion eggs annually) significantly depends on the management efficiency and animal welfare costs that are associated with conventional battery cage systems. The decreased control in cage free systems means that farmers must take into account additional factors that can affect the production, welfare, and mortality of the flock. For

example, feather pecking and increased risks of ectoparasites have been shown to be major risks to the well-being of hens in cage free systems. Due to these additional risk factors, monitoring and management of hens in cage-free systems becomes more difficult and labor intensive. The increase in labor, difficulty in monitoring the hens, and the risk factors, along with the reduced flock size (and production) associated with the cage-free systems can significantly affect the animal welfare and farmer's cost. Therefore, there is a need for technologies that can help the farmers to i) improve the well-being of animals, ii) improve the management and production efficiency, and iii) reduce the production cost of cage-free eggs. To handle these challenges, Novateur Research Solutions propose smart sensing technologies for objective, non-invasive evaluation and monitoring of laying hen flock in cage-free environment that enable i) continuous (24/7) real-time monitoring of the flock using smart sensing systems; ii) automated quantification and continuous tracking of flock behavior; iii) automated identification of behavioral changes; iv) automated identification and early prediction of risks to hen well-being; and v) identification of factors and conditions for optimum production and welfare of the flock.

Animal Health Component

Animal Health Component: 100%

Research Effort Categories

Basic	10%
Applied	30%
Developmental	60%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
307	3210	2020	50%
315	3210	2080	40%
315	3210	1060	10%

Knowledge Area

[307] Animal Management Systems

[315] Animal Welfare/Well-Being and Protection

Subject Of Investigation

[3210] Egg-type chicken, live animal

Field Of Science

[2020] Engineering

[2080] Mathematics and computer sciences

[1060] Biology (whole systems)

Keywords

United States Department of Agriculture
Project Initiation

Laying Hen, Cage Fee System, Deep Learning System, Northern Fowl Mite, Precision Livestock Farming

Goals / Objectives

The prime objective of this effort is to develop a smart sensor-based system that enables efficient management and effective welfare of laying hens in cage-free settings. The key objectives that will be accomplished during Phase II research and development include:Collection and Analysis of Sensor Data from Commercial Cage-Free System: Novateur will collect video and sensor data of both infected and non-infected layer-hen flocks from commercial cage-free systems to enable technology development and validation. The team will collaborate with its industry partners to gain access to commercial cage free layer houses (with and without infected hens) along with egg production and mortality records. The task will involve i) installation of sensors and collection of data, ii) manual analysis of data and identification of behavioral markers and iii) data annotation.Development of Improved Technologies for Automated Visual Monitoring and Behavior Analysis of Laying Hens in Commercial Cage-Free Systems: Based on the research and development work of Phase I, Novateur will develop improved deep learning architectures and models for automated visual monitoring and behavior analysis of laying hens in commercial cage-free systems. The task will involve i) leveraging Phase I deep learning system and newly collected data to train new models for hen detection in commercial settings, ii) improving tracking algorithms to scale to large number of birds in commercial settings, iii) leveraging the deep convolution Long Short-term Memory (LSTM) model from Phase I to train new models of behavioral markers and improving modules for extraction of features and metadata about hen movement from commercial data that can be used to describe activities and behaviors, and iv) development of deep learning system that integrates the information from multiple convolutional LSTM models to predict likelihood of infection at different time-scales.Implementation of an End-to-End Automated Hen Behavior Monitoring System for Poultry Welfare and Management: Novateur will implement an end-to-end software that integrates all the technology components. The algorithms developed under the effort will be ported and optimized for operation on commercial settings. The automated system will be capable of ingesting multiple sensor streams, automatically detect and track multiple hens simultaneously, automatically identify multiple behavioral markers as well as prediction of likelihood of infection in the flock at multiple time scales. Novateur will also develop a user interface that will provide the end-user real-time data about the wellbeing of the flock in an intuitive fashion to enable precision farming.Testing, Evaluation, and Validation of Technology using Data from Commercial Settings: Novateur will perform detailed algorithm level, component level, and system level testing and validation of the system on data from commercial settings

Project Methods

The research, development and evaluation of the proposed technologies will be divided into the following tasks: Data Collection and Analysis: In the Phase II of the project, we will increase the problem scale by collecting data from a commercial cage-free housing. Moreover, we will develop behavior markers and automated system to detect bed bug infestations in addition to northern fowl mites. The team has already collected an initial video dataset using video sensors. Analyses of preliminary data collected from commercial egg farms (including two barns with bed bugs and two barns without bed bugs) indicated that there are some differences in welfare scores (feather damage and keel bone damage) and productivity between birds in barns that are infested with bed bugs and birds in barns that do not have bed bugs. However, further research is needed to examine how behavior differs among birds in infested barns and birds in "clean" barns so that the effects of parasites on hen behavior can be determined. During the Phase II effort, the Team will continue to collect and analyze this data from commercial farms to identify behavior markers. The videos will also be annotated to support algorithm development, model training, and system validation.Improvement of Algorithms for Automated Detection, Tracking, and Analysis of Hen Behavior in Commercial Settings:The subtasks under this effort include: i) Improved Hen Detection Module: During the Phase II effort, the team will further improve the detector models that were developed in Phase I research with additional training data from commercial setting. This will require manual annotation of training data as well as validation data from collected imagery. This will be accomplished by leveraging Novateur's existing tools that enable rapid annotation of videos.ii) Improved Hen Tracking Module: A key challenge in commercial settings is the large number of hens that are present in an image frame at any

given time. This causes several challenges for tracking system that include, complex target interaction, noisy observations, and ambiguity between targets due to their spatial proximity and appearance similarity. To handle this, we will develop target-specific and background-aware appearance models that optimize discrimination of each object from their surroundings. Another major challenge is real-time processing of large number of hens. This will be achieved by both algorithm and software optimization.iii) Improved Behavior Analysis Module: The Phase II effort will extend the algorithms developed for hen behavior analysis by developing models of additional key behavioral markers, e.g. pecking from trajectory and image features. These markers will be informed by the analysis of video data collected at commercial farms with bed bug infestation. The new models will be developed by extracting the features from automatic detection and tracking of hens in the videos and then training the deep convolutional Long Short-term Memory (LSTM) network from annotated data (labeled based on hen activity).Development and Optimization of an End-to-End Automated Hen Behavior Monitoring System for Poultry Welfare and Management: Novateur will integrate various system modules in an end-to-end software that will be able to ingest sensor data and generate real-time indicators about the poultry welfare. This will include system design and prototyping, implementation of software architecture, interfaces, data-structures, and communication protocols in accordance with available technologies. The prototyping will be done in C++ in a modular fashion for efficient performance and ease of transition and integration in the future efforts. Existing Phase I Python code as well as any Phase II research code will be ported to C++ and optimized for performance using CUDA for GPU-based parallel processing of video data.Design of User Interface and feedback from End Users: During the Phase II effort, Novateur will also develop a user-interface that will provide real-time welfare status of the flock under observation in an intuitive graphical fashion. This will include behavioral metrics and activity indicators, such as preening, pecking, perching, etc. as well as likelihoods of various types of infestation. The Team will also obtain feedback about the user requirements from the end-users and use them to guide the initial interface design process.Testing and Validation: We will use an iterative approach for development and testing of different features of the proposed system where each iteration will consist of the full software lifecycle, including design, development, and testing. This agile methodology of software development and testing will enable us to mitigate the development risks and will provide flexibility to adapt to unseen challenges. The behavior changes with the progression of the mite infestation will be evaluated using observed behavior. Finally, the relationship between the measurements and the predicted behavior will be analyzed, for example, by computing the correlation of prediction scores and their statistical significance with the measurements, and the assessment will be performed to validate whether the changes in behavior detected using the system are associated with the measures of hen welfare.